Crosscutting Industrial Applications of a New Class of Ultrahard Borides

Benefits

Energy savings from development of ultrahard borides are expected to occur in a number of areas:

- A 10% market in the current U.S. metalcasting industry (grinding operations) may result in total energy savings of 5 trillion Btu per year.
- Use in only 10% of mechanical pulping operations (compared with conventional grinding techniques) can result in an overall energy savings of 250 billion Btu per year.
- A 1% improvement in performance in the mining industry' drilling, coring, boring, and grinding equipment would result in direct savings of $10 million per year. A more efficient grinding tool that enables a 25% increase in speed on minerals above the speed possible wih current materials could lower energy demands by 100 billion Btu with only 10% of the market.
- A 2.5% reduction in electric power consumed for cutting operations industry-wide may result in reducing CO_2 emission in the United States by 2 x 10^6 metric tons.

Applications

Because of the wide range of possible applications for ultrahard boride, this project describes a broad-based effort to develop and transfer this technology to four key industries:

- **Agriculture:** Improving the durability of ground-contact tools and silage-chopping devices.
- **Forest Products:** Improving mechanical-grinding and wood-pulping operations.
- **Metalcasting:** Increasing domestic productivity in grinding and finishing applications.
- **Mining:** Augmenting existing drilling technology (i.e., drill bits to cut granite).

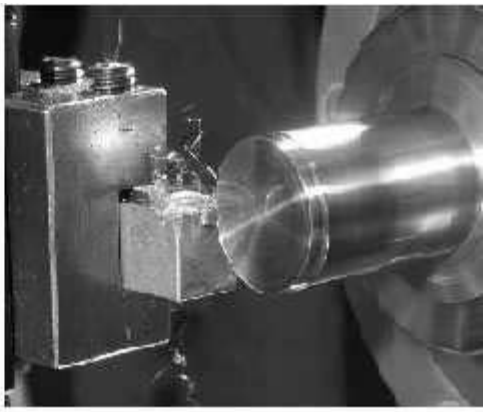
New $AlMgB_{14}$-Based Hard Materials Can Enable Improved Industrial Grinding and Cutting Operations

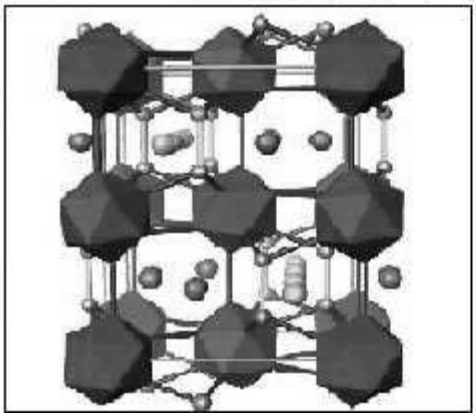
This project offers substantial benefits to the IOF industries. The proposed technology would increase the efficiency and decrease the cost of machining, cutting, finishing, and grinding operations. Current-generation ultrahard materials for these applications impose severe limitations on manufacturers, which limits their use in industry.

The key characteristics of hardness, wear resistance, fracture toughness, formability, and low cost are materials design goals that span a wide range of applications and have relevance to all four industries identified.

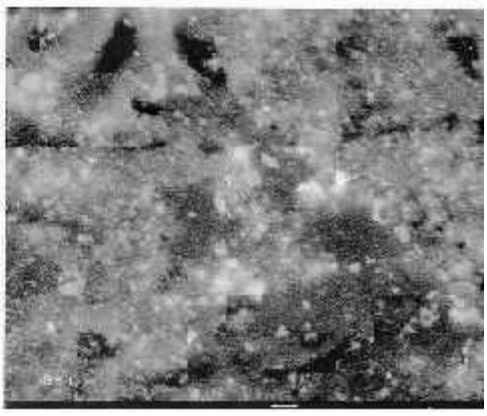
High-speed grinding of cast iron using ultrahard boride

Laboratory-scale lathe cutting tests of boride on 304 stainless steel





Crystal structure of ultrahard boride



Typical microstructure of ultrahard boride prepared by Ames Laboratory method

Project Description

Goal: The goal of this project is to develop a new class of ultrahard materials, based on the complex boride $AlMgB_{14}$, into high-performance, cost-effective solutions for a wide range of key industrial focus areas, including metalcasting, forest products, mining, and agriculture.

Issues: Over 250,000 different types and sizes of grinding wheels are manufactured; however, only a small percentage are manufactured from superabrasives, due to their prohibitive cost. The properties most important to abrasives are hardness, nonreactivity, low cost, and friability (the ability to incrementally fracture into smaller pieces and self-sharpen). The bulk ultrahard borides appear to possess these desirable characteristics, suggesting that they may have a significant impact on the IOF industries by making high-performance grinding and finishing wheels and drill bits more efficient and affordable.

Some of the challenges to be addressed in the development of the new $AlMgB_{14}$ technology will be to understand and control the formation of deleterious oxide phases during processing, to identify appropriate large-scale mechanical alloying techniques best suited for processing nanometric boride, and to characterize properties such as its low ductility and impact resistance (fracture toughness).

Approach: The R&D activities will focus on the following tasks:
- Understanding and quantifying the development of composition, microstucture, and second phase additions (e.g., Si and TiB_2) on the cutting performance, wear resistance, and toughness of the $AlMgB_{14}$-based polycrystalline.
- Characterization of microhardness, fracture toughness, and wear rate of a series of hot-pressed tools and high-velocity oxygen fuel (HVOF)-sprayed coatings prepared with varying additive content.
- Application in tool design and cutting technology.
- Preparation and testing of monolithic “tools” using a variety of protocols representative of conditions experienced in each of the four target IOF industries.

Potential payoff: Development of this new industrial material is expected to result in significant impact on various IOF industries.

The time and energy required for machining/cutting/grinding/chopping will decrease, compared with those of existing technology, by implementation of a superhard, yet chemically inert, abrasive material. This benefit translates directly into increased energy efficiency, higher cutting speeds, and faster material removal.

Progress and Milestones

- Alloy (composition) and process development.
- Introducing controlled second phase additions for hardness and wear improvements.
- Microanalytical characterization and characterization of relevant physical properties.
- Mechanical alloying scale-up and tool design.
- Development of bulk and coatings of the materials.
- Laboratory cutting/grinding/chopping tests.
- Focus area input and evaluation of materials in the metalcasting, mining, forest products, and agriculture industries.

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